PERFORMANCE EVALUATION OF A REVERSIBLE FLOW DOUBLE SKIN FACADE

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ABSTRACT

Double-skin facade (DSF) is an architectural/ engineering solution developed from the need to increase comfort in buildings with full glazed facades. The actual concept of holistic approaches to the building energy system considers DSF as an element of an Advanced Integrated Facade.

DSF were developed for colder climates and uncertainty remains on their applicability to warmer areas due to higher probability of overheating. Moreover there is a need for data in order to properly evaluate how they work from comfort and energy use points of view and to improve and validate models and predictions from design tools (Hoseggen *et al.*, 2008).

In order to evaluate the thermal behaviour of such a facade LNEC (39º N) assembled a south facing test facility allowing changing among some of the possible configurations. Being a reversible flow type of DSF it means that it is possible to test configurations such as (according to the classification established within the IEA ANNEX 44 (Marques da Silva and Gosselin, 2006)): Outdoor Air Curtain (OAC); Indoor Air Curtain (IAC); Exhaust Air (EA), or; Supply Air (SA). It is also possible to use any kind of ventilation type, the layout being established as a box window (BW) or, as a limit, a Buffer (Bf) configuration. Some of these DSF configurations have been tested by others authors through either test cells experiments (Saelens, 2002) or field monitoring (Corgnati *et al.*,2003; Marques da Silva *et al.,* 2005, 2006, 2008 – within IEA-ECBCS Annex 44).

The main goal to achieve consists on assembling an hybrid ventilation system based on the DSF, the project's first phase being the establishment of an appropriate type and position of the shadow device. The first type tested, and reported here, is a roller blind and results show that it's position within the DSF gap, as well the flow path, has influence on air temperatures.

1. TEST FACILITY

The glazed façade has dimensions of 2.5m height and 3.5m length, the gap depth being of 0.20 m. The outer pane has a simple annealed 5 mm glass (U=5,7 W/m2/K; Tv=87%; Te=75%; Ae=18%; g=0,80) and the inner one is a low emissive (U=1,4 W/m2/K; Tv=69%; Te=36%, Ae=34%+3%; g=0,41) double glass (6-16-5). The shading device is a gray roller blind.

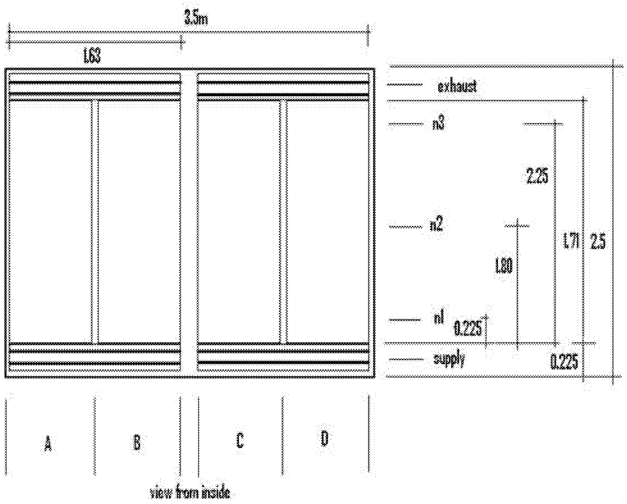


Figure 1 – Test cell layout and measurement levels

The gap has eight sets of louvers, 0.225m high and 1.63m long each, four in the outer pane and four in the inner one, the blades position being adjustable between fully closed and fully open (blades perpendicular to the façade plane). The room behind the façade (lxdxh - 3.6x3.7x2.8 m^3) is, at present, empty and no climatized. Natural ventilation is possible trough an adjacent corridor. There is no shading from neighbour obstacles

2. MONITORING CASES

This paper reports the monitoring campaigns carried out between July 2007 and January 2008 having in mind the evaluation of the thermal behaviour of the different tested configurations and also the changes of temperature within the DSF gap. Two positions of the shading device were also tested: midway between glazed panes and closer to the inner pane.

Monitoring includes temperature measurements (thermocouple) in all glazing panes, cavity air on bottom, top and on both sides of shading, and heat flux measurements on cavity facing glazing. All data was recorded by a Datataker logger.

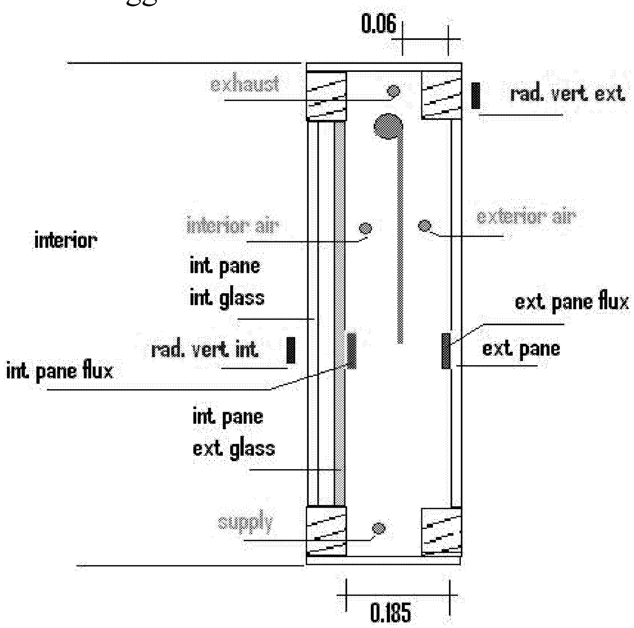


Figure 2 – DSF measurement layout

Environmental parameters were also measured: outdoor and indoor temperature (with Gemini stand alone loggersand solar radiation on horizontal and vertical (indoor and outdoor) planes (with pyranometers).

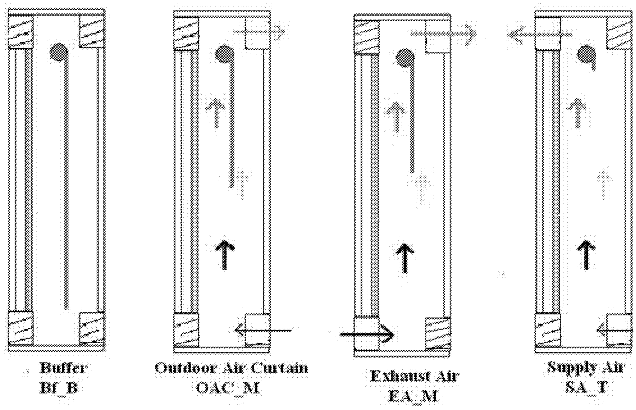


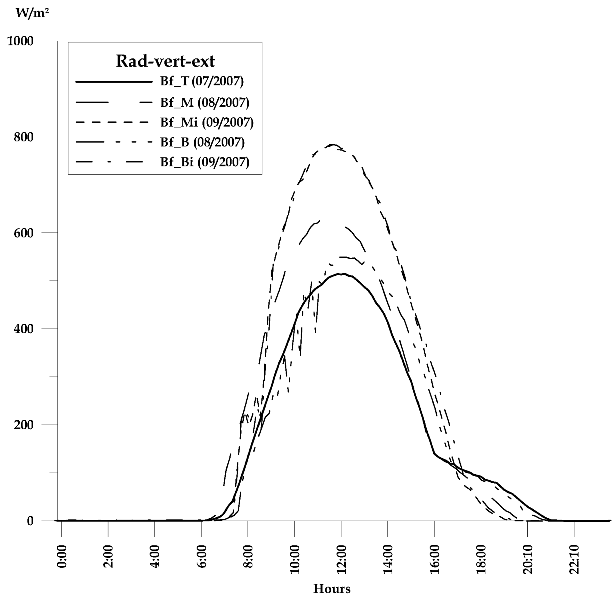
Figure 3 – DSF configurations

Measurements were recorded as 10 minutes averages from 30 seconds readings.

Measurements considered in this paper refer to the following DSF configurations (Fig.3): Bf; OAC; EA; and SA. The letter after the configuration (**_X) refers to the roller blind position – Bottom, Medium, Top -, and the "i" refers to the shading inner position.

The following Figures show the environmental conditions for the test results presented. Incident radiation on the vertical plane of the DSF varies between a minimum of 500 W/m^2 (July 2007) and a maximum of 900 W/m^2 (January 2008).

Maximum temperatures show a minimum of 15ºC in January 2008 and a maximum of 38ºC in July 2007



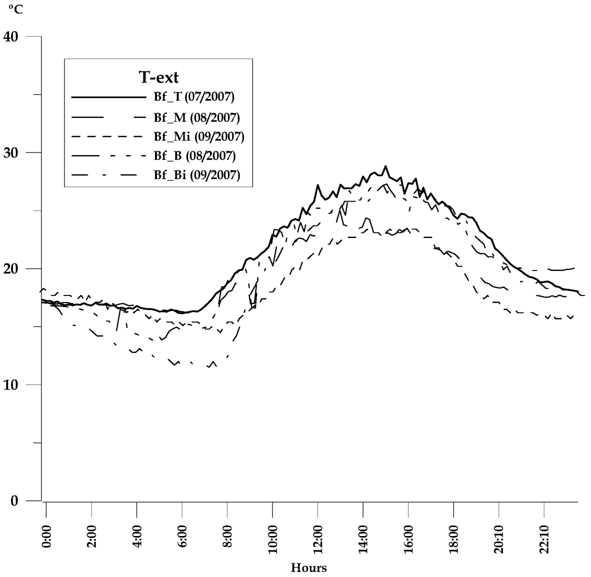


Figure 4 – Outdoor incident radiation on a vertical surface and temperatures for Bf configuration.

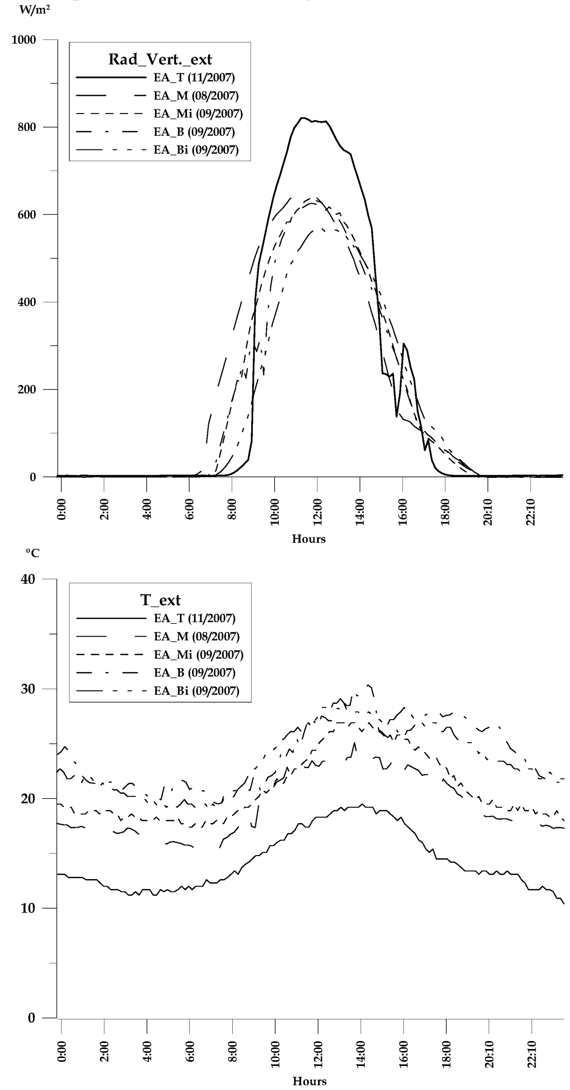


Figure 5 – Outdoor incident radiation on a vertical surface and temperatures for EA configuration.

3. MONITORING RESULTS

The main goal of the work presented here is to evaluate the combined influence of DSF configuration and shading position inside the cavity.

Results are presented as temperature differences between:

i) midlevel (n2, Fig.1) inner and outer sides of shading - dT_g(ain-aext);

ii) bulk cavity to outdoor – dT(gap$_{bulk}$-ext); and,

iii)outdoor to indoor – dT(ind-outd).

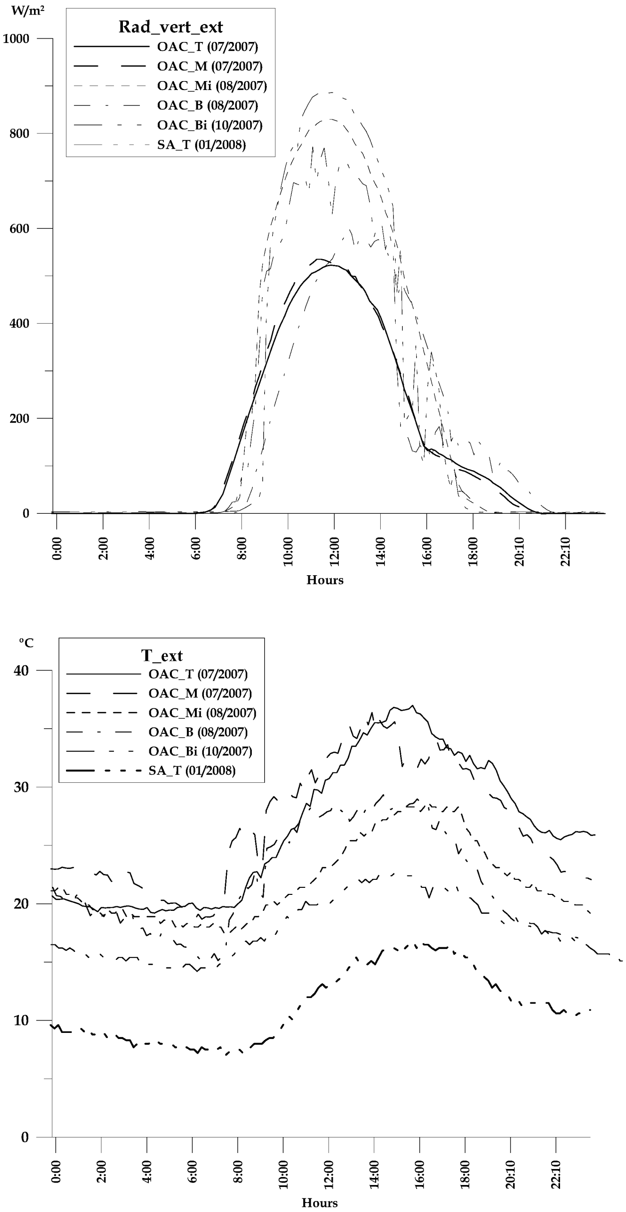


Figure 6 – Outdoor incident radiation on a vertical surface and temperatures for OAC and SA configurations.

Major differences between the two air layers – around 10K higher in the inner layer - occurs when the roller blind is fully lowered for the Bf (Fig.7) and OAC (Fig.9) configurations. This was an expected behaviour due to the proximity of the heated roller blind to the inner pane. Note that this does not happen for the EA configuration (Fig.8) because the air admitted from inside will naturally flow also behind the roller blind.

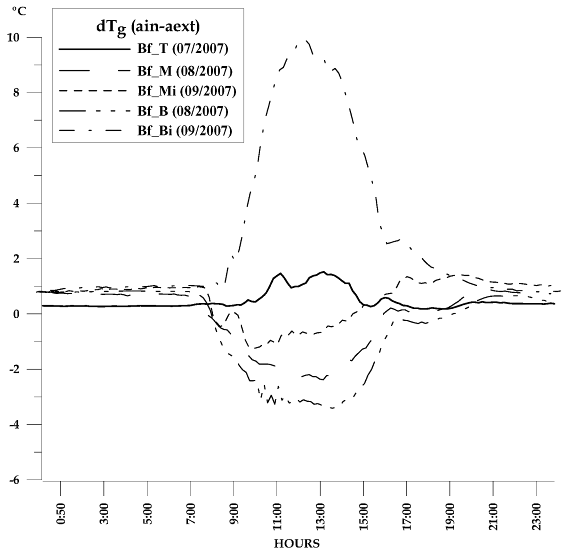


Figure 7 – Temperature differences between midlevel (n2, Fig.1) inner and outer sides of shading for Bf configuration.

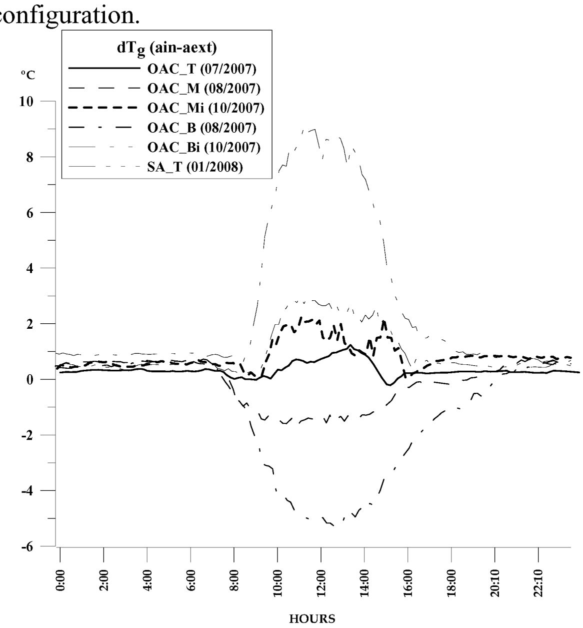


Figure 8 – Temperature differences between midlevel (n2,Fig.1) inner and outer sides of shading for EA configuration.

With no shadowing in the cavity there is always a temperature difference probably due to the asymmetric temperatures conditions of DSF glasses and subsequent convection currents inside the gap (Gratia *et al.* 2007)

The inner layer is clearly cooler than the outer layer for the centred position of the roller blind within the gap, on its lower position. The temperature difference is reduced as the roller blind is raised.

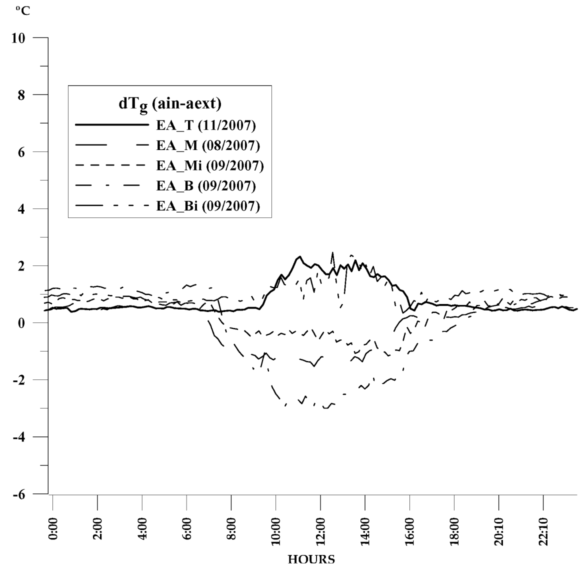


Figure 9 – Temperature differences between midlevel (n2, Fig.1) inner and outer sides of shading for OAC and SA configurations.

When looking into the difference between the average DSF gap and outdoor temperatures, Figures 10-12, one can find similar patterns among configurations or shadowing positions.

The absence of ventilation (Bf configuration,. Fig.10) induces the higher temperatures in the DSF gap, as expected - 14K<dT<34K.

When gap ventilation is present maximum values reach the same level (~15K) and the lowest occurs for OAC configuration, ~6K, (Fig.12) if the roller blind is centred within the gap. These results are in agreement with Gratia *et al* (2007) numerical study where the higher cooling loads were also observed for the blind placed close to the inner skin.

Finally we will look into the influence on indoor temperature expressed as the difference to outdoor temperature, Figure 13-15.

A first note for the EA configuration (Fig.15) showing a temperature difference almost independent of the roller blind position due to fact that DSF gap air flows from indoor.

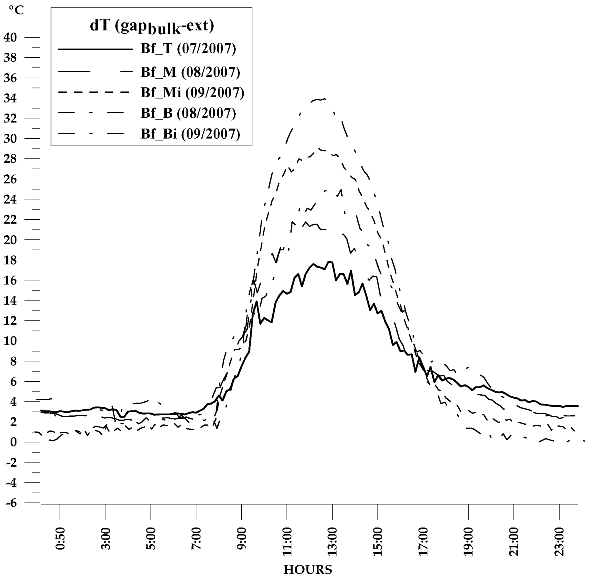


Figure 10 – Temperature differences between the average DSF gap and outdoor for Bf configuration.

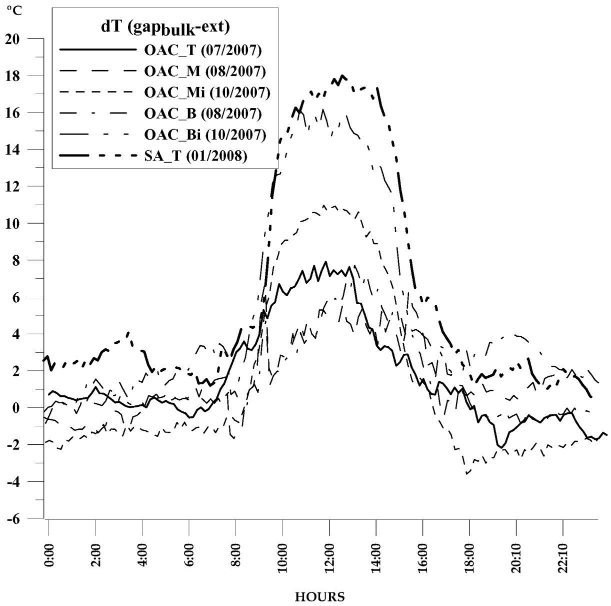


Figure 12 – Temperature differences between the average DSF gap and outdoor for OAC and SA configurations.

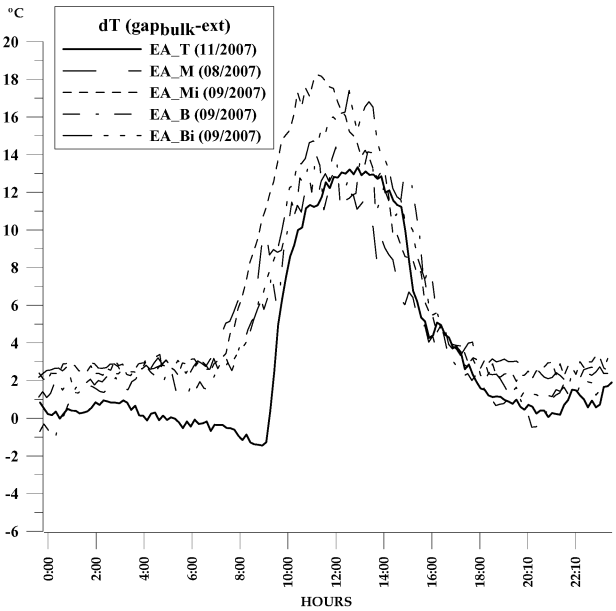


Figure 11 – Temperature differences between the average DSF gap and outdoor for EA configuration

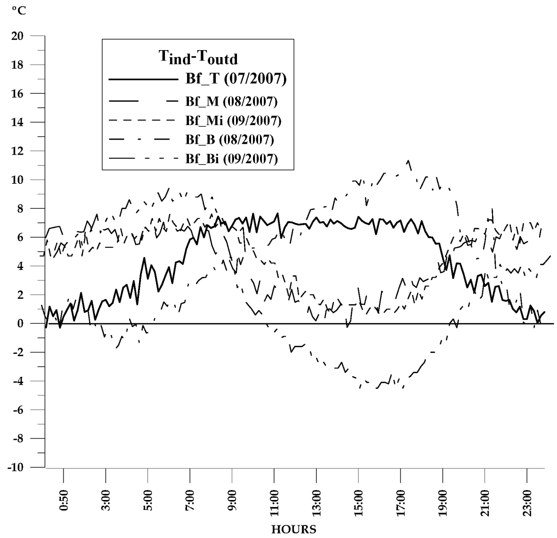


Figure 13 – Temperature differences indoor and outdoor for Bf configuration.

Also to note that on sunshine hours dT is close to 0K or slightly negative due to the increase of air flow promoted by the stack effect within the DSF gap. The reverse situation is clear during the night period.

For the buffer configuration (Fig.13) indoor temperature is always higher than outdoors with the exception of the lowered roller blind closer to the inner pane during sunshine hours

The OAC configuration (Fig.14) shows the higher temperature differences between indoor and outdoor, reaching 10K for the no shading and mid height (centred) position. This can be explained by the highest stack effect and the reduced head loss within the gap, together with the thermal resistance of the inner pane. All other configurations show negative, but smaller, values during sunshine hour.

The supply configuration (Fig.14) allows, as expected, a positive difference during almost all day.

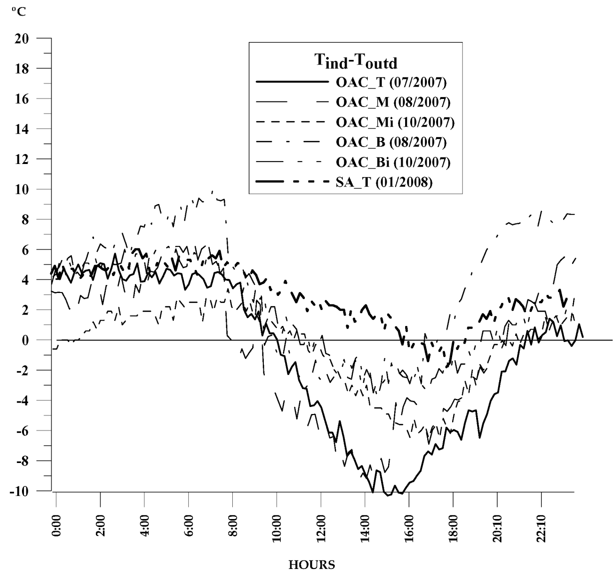


Figure 14 – Temperature differences indoor and outdoor for OAC and SA configurations.

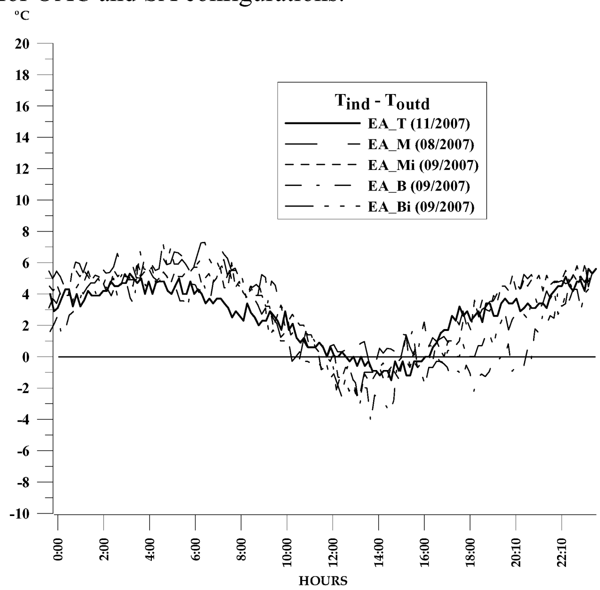


Figure 15 – Temperature differences indoor and outdoor for EA configuration.

4. COMMENTS

This paper reports a monitoring campaign performed at a double skin façade test cell allowing changing the DSF configuration concerning the flow path and the shading position.

It is shown that the position of the shading device (dark gray roller blind) has influence on the temperature distribution within the DSF gap, mainly if it is positioned close to the inner pane.

The DSF gap ventilation proves to be determinant on the bulk air temperature within the cavity, whereas the shading position and DSF configuration influencing the absolute air temperatures but not its global trend.

In what concerns the indoor temperature, when compared to the outdoors, one has to have in mind that, at the present stage, the test cell is not fully prepared to take final conclusions. The aim of the present tests is to obtain DSF behaviour and general trends on its influence indoors.

The related results are encouraging in our purposes to use the reversible flow DSF to promote warmer air removal or supply depending on the needs.

5. ACKNOWLEDGEMENTS

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